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19. (Amended) An apparatus for reducing the parachuting of a probe measuring the topography of a surface comprising:

an oscillating probe;

parachuting detection circuitry coupled to the oscillating probe;

parachuting reduction circuitry coupled to the parachuting detection circuitry, wherein the parachuting reduction circuitry reduces the parachuting of the probe in response to the detection of parachuting of the probe.

REMARKS

Entry of the above amendments is respectfully requested. With respect to the drawings, Applicant directs the Examiner to the attached Request to Approve Drawing Changes filed on even date herewith. Applicant adds the "phase detection circuit" 212 (Figure 2) (described in the specification at pages 6-10), and amends Figure 1 to illustrate (1) the standard "oscillating drive signal," (2) a conventional deflection detection scheme, with conventional displacement detector 105, and (3) the analog multiplier 590, also shown in Figure 5. The deflection scheme is described briefly in the specification at page 8, lines 3-9, now amended as shown in the attached Appendix hereto. Such a scheme is conventional as shown and described in U.S. Patent No. 6,008,489, cited by the Examiner and owned by the present assignee.

Also, Applicant has amended the specification at page 8 to clarify the detection scheme now shown in amended Figure 1, at page 9 to reference the phase detection circuit 212 now shown in amended Figure 2, and at page 12 to correct typographical errors. Entry is respectfully requested.

In the Office Action, the Examiner objected to the title of the invention. Applicant respectfully traverses this rejection. Each of the claims of the present application is specifically directed to reducing the phenomenon known in the art of atomic force microscopy where the

probe periodically oscillates freely during scanning due to a parachuting effect (e.g., at sharp ledges). The present invention is specifically directed to compensating for this phenomenon during an AFM scan. Should the Examiner wish to discuss this further, he is invited to contact the undersigned at the number below.

Next, the Examiner rejected claims 1-8, 10 and 11-20 under 35 U.S.C. § 112, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention. In particular, with respect to claim 1, the Examiner states that it is unclear what "a phase detection circuit" represents. The "phase detection circuit" is a part of the detector module (210), as suggested by the Examiner, and discussed on page 3, lines 9-19 and pages 9 and 10 of the "Detailed Description of the Preferred Embodiments." This is further highlighted by the change to Figure 2 which is being submitted herewith. The "phase detection circuit" is a conventional component, see, for example, U.S. Patent No. 6,008,489.

The Examiner next states that claim 2 includes an inaccuracy regarding the "envelope detector" which is coupled to the precision full wave rectifier (520). Applicant disagrees. The envelope detector, although in the preferred embodiment is directly connected to the clamp and gain circuit (530), as stated by the Examiner, is operatively coupled to the precision full wave rectifier (520), via the clamp and gain stage (530), as shown in Figure 5 illustrating the preferred embodiment.

Next, in claim 4, the Examiner states that it is unclear whether the "event detector" is the same as the "event detector and hold off circuit." Applicant agrees and has amended claim 4, as well as claim 5, accordingly.

The Examiner then rejects claim 5 stating that the limitation regarding "multiplier coupled to the event detector" is inaccurate. Similar to the limitation associated with claim 2 described above, although in the preferred embodiment the multiplier is not directly coupled to

the event detector, it is nevertheless operatively coupled to the event detector, via the event level setting circuit (580).

The Examiner next makes similar rejections with respect to claims 6 and 10, and again, applicant disagrees with the Examiner that the limitations defined therein are inaccurate. In the case of claim 6, the event level setting circuit (580) is clearly operatively coupled between the event detector and hold off circuit (560) and the multiplier (590), as shown in Figure 5.

With respect to claim 10, the Examiner states that it is necessary to clamp and gain the output signals from the rectifier prior to the envelope detecting step. Applicant respectfully disagrees. Although the clamp and gain circuit (530) is preferably included to adjust the amplitude of the rectified phase input signal, and thus optimize performance of the envelope detector circuit (530) is not mandatory for operation.

The Examiner also rejects claim 12 stating that it is unclear which device is used for triggering an event signal. With reference to Figure 5, the device used for triggering an event signal is the comparator (550) which compares the detected envelope with the parachuting phase offset in free oscillation, as shown and described in conjunction with Figures 6, 7 and 9. Applicant has amended claim 12 to clarify this aspect of the invention.

With respect to claim 13, the device used to delay the generation of the event trigger signal is the event detector and hold off circuit (560) that produces waveform (d) shown in Figure 8, and described, for example, on page 11.

In claims 15 and 16, the Examiner states that it is unclear which device is used to detect an error signal of the probe and accumulate an error signal. Applicant understands the Examiner's confusion and directs the Examiner to amended Figure 1, as well as to page 7, lines 4-10, amended page 8, lines 3-22,and page 12, lines 3-14 which discuss the displacement detector 105 (Fig. 1 as amended) and control module 150. Note that the amendments to Figure 1 and to the specification at page 8 are being made to simply clarify the use of deflection detection

to monitor cantilever oscillation which is well known to those skilled in the art. The control module 150 determines whether the error signal based on probe oscillation (detected by detector 105) is too high and accumulates the error signal, as defined in claim 15. Similarly, with respect to claim 16, the control module 150 detects the error signal associated with probe oscillation when the oscillating amplitude is too small, and accumulates the error signal of the probe.

In view of the amendments and the above remarks, applicant believes that each of the rejections under 35 U.S.C. § 112, second paragraph, has been overcome and an indication to that effect is respectfully requested.

Next, the Examiner rejected claims 1-20 under 35 U.S.C. § 112, first paragraph, as containing subject matter which has not been described in the specification in such a way as to enable one skilled in the art to make and/or use the invention. In particular, the Examiner states that it is unclear what "a phase circuit," "a detector module" and a "boost module" include. The Examiner additionally asks whether they are well known in the art. With respect to the "phase circuit" or "phase detection circuit," applicant notes that a phase circuit, such as that described in U.S. Patent No. 6,008,489 to Elings et al., is known and understood by those skilled in the art and is shown in amended Figures 2 and 5. With respect to the "detector module," applicant notes that the phase circuit (212) is part of the detector module (210), as shown and amended in Figure 2, and includes the other circuit components indicated in amended Figure 5. The detector module (210), as defined in the claims and described in the specification, is not well known in the art. Similarly, the "boost module," shown in Figure 2 and amended Figure 5, is not well known in the art. In particular, the boost module 220 shown in Figure 2 is a critical component of the present invention which conditions a sensed signal and provides a boost signal to the drive of the cantilever to overcome the "parachuting" problem, as described throughout the present application. Collectively, the detector module (210) and the boost module (220) comprise the paraboost module shown in Figure 1 at 110. A preferred embodiment of the paraboost module is described in the specification at pages 10 and 11, for instance.

In claim 19, the Examiner states that it is unclear what "parachuting detection circuitry" and "parachuting reduction circuitry" are. The "parachuting detection circuitry" is circuitry that is used to detect parachuting. For example, the detection module 210 including the phase detection circuit 212 of amended Figure 2 as described in the specification at page 9, as amended, is "parachuting detection circuitry." The "parachuting reduction circuitry" is circuitry to reduce parachuting, as described in the specification. For example, the boost module 220 shown in Figure 2, (a preferred embodiment of which is shown in Figure 5) is directed to circuitry that is employed to reduce parachuting. Should the Examiner have any further questions in this regard, he is invited to contact the undersigned to discuss the same.

Finally, the Examiner states that, in claim 20, it is unclear what "a phase detection circuit" represents. The "phase detection circuit" is a component that is known in the art and which is now shown in amended Figure 2 at 212 which has been changed via the attached request to approve drawing changes. It is the same "phase detection circuit" that was discussed above with respect to claim 1.

Next, the Examiner rejected claims 1, 9, 19 and 20 under 35 U.S.C. § 103 as being unpatentable over Elings et al. U.S. Patent No. 6,008,489. In particular, the Examiner states that it would be obvious "for one of ordinary skill in the art to consider that the computer (4) is equivalent to boosting circuit since this computer "boosts" a signal to the probe based on the phase signal detected by the detection circuit." Applicant respectfully disagrees. The term "boosting circuit" has a specific meaning as shown and described in the specification of the present application. When the probe tip scans an abrupt drop off or sharp ledge on the sample surface, as shown at 175 of Figure 1, the probe tip no longer taps on the surface and no longer yields faithful data of surface topography. This type of probe status, when the tip no longer tracks the surface, is referred as "parachuting" during scanning. In the control system of a conventional AFM, such as that shown and described in the Elings et al. '489 patent, the Z control module responds only if the tapping amplitude changes. Importantly, the Z control module will not act until the parachuting amplitude increases to "free air" oscillation. The amplitude accumulation rate is a parameter that depends on the mechanical Q of the probe and

the oscillating frequency. This increase normally takes a fraction of a millisecond to a few milliseconds. During this time, the AFM probe is not acquiring surface data. The undesirable compromise which has been implemented in existing AFMs is to scan slowly, so the time the probe stays at a particular location or pixel is longer than the transient time it takes for the oscillating amplitude to increase to free air oscillation. Furthermore, since the topography to be measured is often unknown, the slow down in scanning speed must be uniform for all the pixels. Parachuting of the probe has therefore been a long-standing problem for surface scanning with an AFM, including the AFM disclosed in U.S. Patent No. 6,008,489.

The key concept of the present application is recognizing that although amplitude growth must go through a transient stage during parachuting, the phase response when parachuting occurs is instantaneous and independent of amplitude. More particularly, the phase spectra as a function of frequency are identical regardless of the amplitude spectra which depend on the drive for a given mechanical oscillator. Again, the important difference is that while amplitude takes time to develop into free oscillating amplitude, the phase immediately assumes the free oscillation value. It is this detected phase that is used to indicate a parachuting event. Whenever a probe parachutes on a surface (i.e., an event is detected), the AC oscillator drive power is boosted for a short period by the present invention to help amplitude growth and increase speed of the amplitude change until the probe returns to tracking the surface.

The computer and the control circuitry of the Elings et al. '489 reference is directed to maintaining a set-point separation between the tip and the sample by increasing the gain applied to the error signal. As described in the specification at page 8, lines 10-22 of the present application, a drawback of the Elings et al. system is that the high gain makes the system susceptible to instability of the Z-module (i.e., the piezoelectric actuator). In the present invention, however, such Z-module instability does not occur when the probe is lowered quickly because instead of increasing gain in a feedback loop in response to the amplitude error signal, probe oscillation is increased directly by boosting the probe drive signal. This causes the error signal to accumulate more rapidly in the control module which causes the Z-module 140 to lower

the probe more rapidly. As a result, the Z-module 140 responds to and reduces parachuting of the probe 120 without causing the probe to become unstable.

Overall, the way in which the feedback signals are applied to the actuator of the AFM in the present invention versus in the Elings et al. '489 system is entirely different. One way in which the drive signal is boosted is described at page 11, lines 10-16, where an analog multiplier 590 is used to condition waveform (f) of Figure 9 which is combined with the cantilever drive signal to boost the drive amplitude, thus resulting in waveform (g) as illustrated in Figure 10. This boost of the drive amplitude (waveform (g)) is used to drive the probe 120.

Because the Elings et al. '489 reference does not teach a probe drive boosting circuit that boosts the drive in response to a parachuting event, triggered by detecting phase changes, pending independent claims 1, 9 and 19, and claims 2-8, 10-18 and 20 dependent therefrom, respectively, are non-obvious over the Elings et al. '489 reference.

CONCLUSION

In view of the present amendments and the above remarks, each of the pending claims 1-20 is believed to be in compliance with 35 U.S.C. § 102, 103 and 112. As a result, the claims are believed to be in condition for allowance and an indication to that effect is respectfully requested. Should the Examiner have any questions or comments, the Examiner is invited to contact the undersigned at the telephone number appearing below.

A one (1) month Request for Extension of Time is enclosed. The Director is authorized to direct the fee of $110.00 and any additional fees associated with this or any other communication, or credit any overpayment, to Deposit Account 50-1170.

Respectfully submitted,

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APPENDIX SHOWING THE CHANGES FOR SN 09/761,792

In The Drawings:

Applicant, in response to the objection by the Examiner, submits the attached "Request to Approve Drawing Changes."

In The Specification:

Please amend the specification at page 8, lines 3-22, as follows:

In controlling the Z-module, the paraboost module 110 detects oscillation amplitude, phase, and/or other properties of the probe 120. These properties are detected, for example, by processing the signals produced by any number of standard detector schemes, such as a laser reflecting off the back side of the cantilever and onto a bi-cell or quad detector 105. An error signal from the detector is sent to the control module 150. If the oscillation amplitude of the probe 120 is too high, for example, the non-zero error signal is integrated and accumulated by the control module 150. When enough error signal is integrated, the control module150 commands the Z-module 140 to lower the probe 120 towards the surface 170. The error is integrated so that abrupt changes are not detected too quickly, which may cause the Z-module 140 to engage in unwanted oscillation. If the probe 120 encounters a deep recess 175 in the surface 170, it is desirable to lower the probe 120 to the bottom of the recess 175 as quickly as possible. In conventional devices, this is accomplished by increasing the gain of the error signal. Unfortunately, high gain makes the system susceptible to instability of the Z-module. In the present invention, however, no such Z-module instability occurs when the probe is lowered quickly because instead of increasing gain of the error signal, probe oscillation is increased by boosting the probe drive signal. This causes the error signal to accumulate more rapidly in the control module 150 which causes the Z-module140 to lower the probe 120 more rapidly. Therefore, the Z-module 140 responds to and reduces parachuting of the probe 120 without causing the probe to oscillate or become unstable.

Please amend the specification at page 9, lines 8-17, as follows:

Fig. 2 is an exemplary block diagram of a paraboost module 110 according to a preferred embodiment. The paraboost module 110 includes a detector module 210 and a boost module 220. In operation, the detector module 210 detects the phase of the oscillating probe 120 with a phase detection circuit 212. When the detector module 210 detects the reduction of a vibration of the phase signal from the probe 120, the detector module 210 instructs the boost module 220 to increase the oscillator 130 drive signal supplied to the control module 150 to increase the amplitude of the oscillating probe 120. By boosting the drive to the oscillating probe 120, the vibration amplitude of the cantilever 120 is increased, the error signal is increased, and the control module 150 integrates the error more quickly. Accordingly, the Z-module 140 is instructed to lower the probe 120 towards the surface 170 faster.

Please amend the specification at page 12, lines 3-13, as follows:

Fig. 12 is an exemplary illustration of resulting signals when the paraboost module 110 is used while [and] other [experiment of] experimental conditions are identical to those associated with [in] Fig. 11. The signals include the mapped surface signal 1210, the phase signal 1220, and the amplitude of the drive signal 1230. As illustrated, when the paraboost module 110 detects a leveling of the phase signal 1220 at point 1225 indicating an abrupt drop in the surface 170 at point 1215, the amplitude of the drive signal 1230 is adjusted at point 1235. In particular, the leveling of the phase signal is a reduction of the variation of a phase signal from the probe 120. Thus, the leveling is a quieting of the phase signal from the probe 120. Therefore, the paraboost module boosts the cantilever drive signal, the control module 150 integrates the error more rapidly and the Z-module 140 lowers the probe 120 faster. Accordingly, as shown in signal 1210, an abrupt variation in the surface 170 is more accurately detected.

In The Claims:

Please amend claims 4, 5, 12, 13 and 19, as follows:

4. (Amended) The apparatus according to claim 3, wherein the phase detection circuit further comprises a multiplier coupled to the event detector and hold off circuit,

wherein the multiplier combines the event signal with a probe drive signal to produce the boosted probe drive signal.

5. (Amended) The apparatus according to claim 3, wherein the phase detection circuit further comprises:

a multiplier coupled to the event detector and hold off circuit; and

a control module, wherein the multiplier combines the event signal with a gain setting in the control module to increase error integration.

12. (Amended) The method according to claim 1, wherein the detecting step further comprising [triggering] generating an event trigger signal based on the detected phase signal with a comparator and the boosting step further comprises boosting the drive signal of the probe by combining the event trigger signal with the drive signal of the probe to produce a boosted drive amplitude signal.

13. (Amended) The method according to claim 12, wherein the detecting step further comprises delaying the [triggering] generation of the event trigger signal for a predetermined time.

19. (Amended) An apparatus for reducing the parachuting of a probe measuring the topography of a surface comprising:

an oscillating probe;

parachuting detection circuitry coupled to the oscillating probe;

parachuting reduction circuitry coupled to the parachuting detection circuitry, wherein the parachuting reduction circuitry reduces the parachuting of the probe in response to the detection of parachuting of the probe.